## Indra: An Agent-Based Modeling System

### I. Introduction

Indra is the outcome of a long-standing interest in using agent-based modeling (ABM) to explore social interactions. Most specifically, I have long believed that ABM offers a way to formalize and make accessible to mainstream economists important insights from Austrian economics. (Paul Krugman once asked, “If the Austrian’s Business Cycle Theory is any good, where is their model?”) Hayek gave up on the *Pure Theory of Capital* because he lacked the technical tools to complete it: I suggest ABM might have provided that tool.

But why an ABM framework? Part of this is simply cockiness: I believe I can write a large programming framework better than have others. But it is not merely that: While there are existing ABM frameworks, this one is written with the aim of modeling Austrian capital theory at its core (although it enables the creation of many other types of models as well). As such, it ought to be easiest to create such a model using this framework.

### II. What Is a Model?

Let us open with some philosophical considerations, of two varieties: In this section, we will examine the scientific status of models of this sort, as they are a fairly recent phenomena and it may not be obvious what value, if any, they have. In the next, we will take a brief look at the metaphysical considerations governing the building of the framework itself.

1) Models are constructed.  
2) They are made of distinct parts. (E.g., "a supply curve, a demand curve, an x-axis, a y-axis," or "red lines for highways, black lines for local roads, dashed lines for dirt roads.")

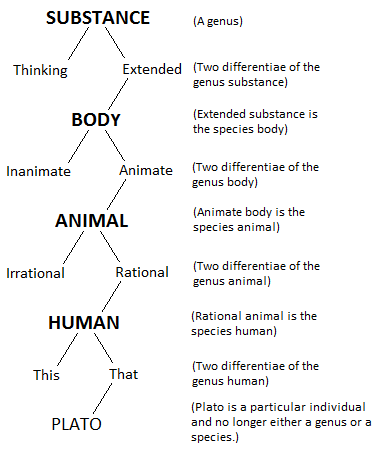
3) The parts are made to fit together. (The supply curve is measured in the same units as the demand curve, and crosses it somewhere. The roads are laid out on the same grid, using the same scale.)  
4) We can adjust those parts, either purely mentally, or with our hands (as with an architectural model), or a pencil and eraser (a mechanical drawing), a computer (a weather model), and so on. (In using a map, we actually adjust a "part" we will in: where we are. Sometimes, this part is represented by our finger, as we trace a route, or the mark of a highlighter.)  
5) Adjusting the parts produces an "answer" of some sort from the model: "Oh-oh, if we move that wall there, the stairs won't fit," or "If the supply curve shifts that far right, the new price will be $4.50."  
6) The modeler hopes that the answer produced by the model says something about what will happen when changes occur in (or are deliberately made to) the thing being modeled.

“One such use — the simplest — is conceptually quite close to traditional simulation in operations research. This use arises when equations can be formulated that completely describe a social process, and these equations are explicitly soluble, either analytically or numerically. In the former case, the agent model is merely a tool for presenting results, while in the latter it is a novel kind of Monte Carlo analysis. A second, more commonplace usage of computational agent models arises when mathematical models can be written down but not completely solved. In this case the agent-based model can shed significant light on the solution structure, illustrate dynamical properties of the model, serve to test the dependence of results on parameters and assumptions, and be a source of counter-examples. Finally, there are important classes of problems for which writing down equations is not a useful activity. In such circumstances, resort to agent-based computational models may be the only way available to explore such processes systematically, and constitute a third distinct usage of such models.” (Axtell, 2000)

### How Indra Is Constructed

#### Object-oriented programming and agent models

Object-oriented programming (OOP) and ABM are a natural fit, and we have tried to exploit that dovetailing to the greatest extent possible. OOP, when done properly, presents the world of the model as a Porphyrian tree, where we descend the tree from the most general categories (classes, in OOP) to the most specific. Furthermore, it enables the programmer to “pick up” the characteristics and capabilities of classes further up the tree “for free,” by *inheritance*. So, for instance, in our particular case, we can establish a class Agent that can act with a goal. Then we can move down the tree and create SpatialAgent, that inherits all of Agent’s capabilities, while also having a location in space. Next, we create a class we call MobileAgent that inherits from SpatialAgent and can also move through space. Next, we can create Creature, inheriting all capabilities of MobileAgent while also eating and reproducing.



(Public domain image downloaded from Wikipedia, http://upload.wikimedia.org/wikipedia/commons/e/ea/Porphyrian\_Tree.png.)

While OOP is a natural fit for ABM, we have sought to push beyond the OOP paradigm as well, by beginning to incorporate some concepts from Whitehead’s process philosophy.

#### Whitehead’s process philosophy

Although work on this aspect of the project is in a preliminary stage, some progress has been made on incorporating Alfred North Whitehead’s “process philosophy” into Indra. For our purposes, the major difference between Whitehead’s view and that of the Porphyrian tree is that, for Whitehead, an entity does not have an “essence” existing in a vacuum. Instead, its nature is, to a great extent, determined by its relationships to other entities. In terms of idealist philosophy, rather than entering into merely *external relations*, entities on Whitehead’s view are constituted by *internal relations* (Whitehead, 2014).

### Our Models

The source code for all of these models is open source, and is available online at Indra (2015).

#### Schelling’s Height Model

Schelling (2006) asks what will happen if the genetic engineering of humans advances to the point where we can control the height of our children, and further, that what people generally desire is merely that their own offspring not be “runts”: perhaps, no one wants their child to be in the bottom 10% of heights in the population, recalling how the “runts” got picked on in school.

Schelling notes that since a population *must* have a bottom 10%, it is not possible for everyone at once to ensure that their children are not in the decile. Instead, what will occur is that the effort to see that that is so will result in a increasing average height for humans, a result intended by no one.

Our modeling here shows that Schelling’s intuition can be easily formalized in an ABM.

#### Krugman’s Baby-Sitting Co-op

Krugman (1998) sought to explain his view of recessions by pointing back to a paper by Joan and Richard Sweeney. As he put it:

Well, it turned out that there was a small technical problem. Think about the coupon holdings of a typical couple. During periods when it had few occasions to go out, a couple would probably try to build up a reserve—then run that reserve down when the occasions arose. There would be an averaging out of these demands. One couple would be going out when another was staying at home. But since many couples would be holding reserves of coupons at any given time, the co-op needed to have a fairly large amount of scrip in circulation.

Now what happened in the Sweeneys' co-op was that, for complicated reasons involving the collection and use of dues (paid in scrip), the number of coupons in circulation became quite low. As a result, most couples were anxious to add to their reserves by baby-sitting, reluctant to run them down by going out. But one couple's decision to go out was another's chance to baby-sit; so it became difficult to earn coupons. Knowing this, couples became even more reluctant to use their reserves except on special occasions, reducing baby-sitting opportunities still further.

Our model captures this situation.

Note: Since I am addressing an Austrian group with this paper (at least in its first incarnation), I must note that showing a model is coherent is not the same as showing it applies! The obvious rejoinder to Krugman on this point by “Austerians” is that the real problem was not limited scrip, but fixed babysitting prices.

#### Schelling’s Segregation Model

As Thomas Schelling famously pointed out (2006), it is not necessary for all or even most individuals to want to live in a largely segregated neighborhood for such neighborhoods to arise: all that is needed is for most people not to want to be “too small” a minority in their neighborhood. We have implemented this model, and it indeed plays out as Schelling saw: once a “tolerance” threshold is set somewhat below 50%, neighborhoods will tend to become almost completely segregated.

This model also demonstrates our ability to experiment with these constructs: one of my students has been creating groups with different tolerance levels, adding additional groups, and so forth, with interesting results.

#### A Predator-Prey Model

Based on the insight from Callahan and Hoffman (2015) that many theories of social cycles appear to have a predator-prey dynamic (Insightmaker, 2015) at their core, we sought to build a predator-prey model as the basis for further models exhibiting cyclical behavior.

#### Adam Smith’s Fashion Model

The first successful descendant of our predator-prey model is based upon a passage of Adam Smith’s from *The Theory of Moral Sentiments*:

“Fashion is different from custom, or rather is a particular species of it. That is not the fashion which every body wears, but which those wear who are of a high rank, or character. The graceful, the easy, and commanding manners of the great, joined to the usual richness and magnificence of their dress, give a grace to the very form which they happen to bestow upon it. As long as they continue to use this form, it is connected in our imaginations with the idea of something that is genteel and magnificent, and though in itself it should be indifferent, it seems, on account of this relation, to have something about it that is genteel and magnificent too. As soon as they drop it, it loses all the grace, which it had appeared to possess before, and being now used only by the inferior ranks of people, seems to have something of their meanness and awkwardness.” (Smith, 2015)

#### Edgeworth Box Model

A major concern here was to keep the model “realistic,” in the sense that we did not want our agents to be able to peer inside other agents endowments or utility functions. An agent proposing a trade had to do so blindly, without any knowledge of whether the other agent had any interest in a good at all.

#### Barter Model

Next, we added multiple agents to our Edgeworth Box model. All of the “negotiating” code from the Edgeworth Box model was inherited in this model, and so we found this model relatively trivial to code.

#### Menger Model

Finally, in our Menger model, we are attempting to see money arise from a good gaining increasing acceptance as a medium of exchange. The first attempt to program this model was interesting as an instance of a spectacular failure of our intentions, and a refutation of the idea that a researcher can merely set up an ABM to get whatever outcome they want. In creating the model, the intention was to have gold emerge as the medium of exchange, by first making it the most durable good, and then by adding to the utility of any good whenever someone will accept it in exchange.

What happened with our first attempt was a dramatic illustration of the fact that, when done properly, these models are vehicles for experimentation, and not simply ways to get out of a computer what you put into it: we thought we had given gold durability and utility characteristics that would make it emerge as money. Instead, what happened was that gold treated in the first round of agent interaction, and then never traded again! In fact, we had created a sort of anti-money that would *never* circulate.

The “interesting result” was eventually fixed so that gold did emerge as money. However, it took extensive experimentation with the model to see what had been done “wrong” in the first place. (The chief thing was the gold had been given too low a marginal utility for the first unit an agent would gain or lose.)

### Conclusion

The Indra system has now been developed to the point that it is relatively easy to generate interesting models using the framework it provides. To advance its development, the main thing it needs now is more users.

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